Hearth and Home: Evaluating Quality of Life in the Ancient Greek World

Introduction

The study of domestic architecture and households has been one of the fastest growing and most dynamic areas of Greek archaeology in recent years. The increasing theorisation of the discipline and particular interests in the development of the polis (city-state) and its associated political ideology, as well as interest in gender and social and economic practices have resulted in more widespread analysis of domestic architecture and associated household activity (Hoepfner and Schwandner 1986; Jameson 1990a and b; Nevett 1999; Cahill 2002; Westgate et al eds 2007). Over the last decade, several scholars have proposed that changing architectural forms, construction materials and types of decoration represent increased economic expenditure and thus improved standards of living across the Greek world during the first millennium BC (Morris 2004; 2005; Nevett 2007 216-219). The purpose of this article is to enhance our understanding of quality of life in ancient Greece by moving from focusing on statistics of floor space and construction costs to an evaluation of health and wellbeing of the household. The novelty of this approach lies in combining archaeological evidence for cooking and heating in the ancient Greek home with new non-archaeological research from the disciplines of medicine and public health, (as well as data from experimental archaeology), to reconstruct physical wellbeing in the past, a key criterion in classifications of quality of life. The article sets out to develop a reinterpretation of vernacular buildings bringing to the fore issues of wellbeing, and embodiment in order to enhance the ways that archaeologists and ancient historians examine quality of life in the ancient world.

Evaluating Quality of Life in Ancient Greece

A common thread linking earlier research on vernacular architecture and standards of living has been the assumption that houses of the Iron Age and Early Archaic period were flimsy (Morris 2000:283) and comparatively unsophisticated (Nevett 2007: 205-206) and thus represent a lower standard of living than later periods with different forms of domestic architecture. Morris (2004; 2005) has also made a direct correlation between house size and standards of living; he argued that there was a decline in the size and quality of houses from median Mycenaean sizes around 70m2 to about 50m2 in the tenth and ninth centuries, which he sees as a reflection of economic decline. In the following eighth and seventh centuries mean house size changed little but variation around the mean increased. In the late eighth century, the largest houses became more elaborate displaying greater wealth and at the other end of the scale smaller houses represent poorer households. For example at Zagora around 700 BC, we see the creation of the *Great House,* an exceptionally large house, which covered 256m2 and may have also had a second floor. However, by the late seventh century exceptionally large or small houses became rare and in the sixth and fifth centuries house size appears to have clustered tightly around the mean, which rose to about 125m2 after 525 BC. Morris has argued that there was a three hundred and fifty percent increase in median house size from 800 to 300 BCE (Morris 2004, 2005). The accuracy of these figures has been questioned due to the nature of the archaeological evidence and some have suggested that evidence of daily wages from places like Athens and Delos is more suitable for evaluating real incomes and thus standards of living in the Classical world (Scheidel 2010a).

In Morris's defence, he attempted to support his figures for the increase in median size with evidence for changes to construction materials and increasing frequency of architectural furniture such as drains and roof tiles or the presence of bathtubs as further evidence for economic growth and improved standards of living (Morris 2005: 91-126). The resultant observations are undoubtedly interesting and the application of these kinds of criteria to the ancient world has its uses, particularly as it enables us to use common forms of archaeological evidence as a proxy for economic data. But economic indicators are increasingly recognized as excessively narrow indicators of present day levels of wellbeing and quality of life. Standard of living and quality of life are the result of much more than increased personal wealth. The Human Development Index (HDI), which is published by the United Nations, provides a wider range of characteristics such as life expectancy at birth, level of education as well as economic indicators to calculate levels of development and standards of living (http://hdr.undp.org/en/humandev/). An alternative system, Gross National Happiness (GNH), measures a nation's well-being rather than GDP (http://gnhusa.org/). GNH is based on the premise that the calculation of a nation's *wealth* should value more than economic development including the quality of life of the people (psychological wellbeing, health, use of time, community vitality, education, culture, environment, governance, and standard of living) (http://www.gnhusa.org/about-gnhusa/what-is-gnh/9-dimensions-of-gnh/).

These quantitative and qualitative methods of assessment of the quality of life are very complex. A fundamental question is whether we can use these types of measurement to calculate relative standards of living or quality of life in the ancient world. Even when we are able to decide on a range of appropriate metrics there are empirical problems of how to measure them and methodological ones of how to weigh the different indices (Scheidel 2010: 7). If we take one possible measurement of quality of life such as physical wellbeing it is difficult to assess using archaeological data. There have been claims that average life expectancy rose up to the classical period (Morris 2004), however, the evidence is based on skeletal data whose interpretation remains highly contested (Scheidel 2010: 3). Stature may reflect both net nutrition and disease loads (Steckel 2009; 2013) and is used as an indicator of wellbeing in archaeology, as well as the social sciences and economic history. The frequency of cranial and dental lesions, as well as skeletal abnormalities or traumas can be read as indicative of nutritional status, levels of health and quality of life (see Roberts et al 2000; Roberts et al., 1994; Schepartz et al., eds. 2009 and references therein). Such data are of particular importance because the connection between economic development, including levels of household income or personal wealth, and physical wellbeing is complicated (Arnott 2005: 21-22; Scheidel 2010: 4); however, the data that we could use to assess trends comes from different sized samples that have been calculated with non-standardised methods (Kron 2005).

Building on this established research, one of the main aims of this article is to argue for alternative ways of looking at domestic space in the ancient Greek (and wider Mediterranean) world by exploring houses, from mainland Greece and the Aegean, and which date to different periods of the Iron Age through to the Classical period (a period of around 700 years). I will suggest that a more complete understanding of quality of life in these periods and places can be gained by moving beyond indicators of economic development and thus improved standards of living. This study will present a comprehensive reinterpretation of domestic evidence not as representations or a manifestation of a general trend of improved standards of living but how daily habitual practices in these houses would have influenced quality of life. Importantly, rather than searching for general patterns of economic development, I suggest that quality of life would have differed substantially between different members of a community and not just in different periods and places of the Greek world.

Crucially our knowledge of disease, health status and life expectancy does not depend upon the availability of skeletal or soft tissue evidence. Here, the analysis of quality of life and physical wellbeing in ancient Greece is developed through the examination of the archaeological evidence for the use of biomass fuel in domestic contexts. Osteoarchaeological research has revealed evidence for inflammatory bony reactions on the pleural surfaces of the ribs, probably due to a lung infection (Capasso 2000a and b; Roberts et al. 1994). This type of lesion has been linked to exposure to indoor pollution from smoke produced during combustion of vegetable matter or animal dung to cook food, or to heat houses, or produced during combustion of oil in lamps. Histological assessment of the lungs of ancient human mummies has shown that anthracosis was a regular disorder in the ancient world. In Greece domestic indoor environments are likely to have had a high degree of particulate pollution from indoor combustion of vegetable material.

The research is grounded on an appreciation of the archaeological to identify and interpret historic habitual practices of the home, including biomass combustion, and how these practices varied within sites and at different times. The discussion is based on detailed analysis of three sites (Nichoria, Zagora and Olynthus) that have been used previously as key examples in discussions of social change (Nevett 1999; 2010) and rising standards of living in the ancient Greek world (Morris 2004; 2005) (Figure 1). Current medical research and the results of experimental archaeology are used to highlight the possibilities in the interpretation of the patterns observed in the archaeological record rather than to dictate interpretation from the start. The comparison of these data sets generates hypotheses that will enrich our current understanding of the Greek world in the first millennium BC. My focus is necessarily narrow, looking predominantly at three key sites. However, clearly, the issues raised within the article are of much broader relevance to the discipline as a whole, with implications for our appreciation of life across the ancient world.

Figure 1. Map of Greece with the location of archaeological sites discussed in the text

Hearths and Homes

Nichoria, in Messenia in the southwest Peloponnese, provides one of the most extensive accounts of settlement and domestic space during Dark Age II-III (975-750 BC) (McDonald and Coulson 1983: 319). Consequently, the site has often been presented as an example of what a typical, small Early Iron Age semi-structured settlement would have looked like. Unit IV-1, an apsidal building made from perishable material including mudbrick and thatch, provides the most complete evidence of a structure and was the largest and the best preserved of DA II and II-III. Even though there is some debate over the exact function of the structure, it has often been used to illustrate the types of houses and domestic activities that occurred in Iron Age Greece (Figure 2).

An alternative form of house can be found at Zagora on Andros, which flourished during the Geometric Period (tenth-eighth century BC/ 925-700 BC). The walls were built of stone slabs that formed small rectilinear rooms. Two major episodes of construction have been identified. In the first period, the buildings bear some resemblance to Nichorian structures, as they comprised a single large room and porch. In the second phase, between 725 and 700 BC, the large rooms of a number of houses were subdivided, some houses were amalgamated and further units including courtyards were built on to provide more living space.

At Nichoria and Zagora there was evidence for the use of hearths inside and out of the structures. In

Unit IV-1, the main hearth was located in the centre of Room 1 (Figure 2). Although it has been argued that the pit hearth was not used in a later period of use, there are still clear signs of the use of fire within the structure. The dark coloured occupation layer and the carbonised seeds seem to indicate that cooking continued to take place inside Rooms 1 and 3. In Zagora, there were schist block hearths in a central position of rooms D16, H19, H22 and H41 (Figure 3). Four horizontal schist slabs were used to form the hearth. The hearths were similar in size (D16 e-w 0.47m, n-s 0.53m; H19 e-w 0.61m, n-s 0.71m, H22 e-w is 0.93m and H41 0.54m e-w, n-s 0.72m) (Cambitoglou et al 1971: 26, 31, 66; Cambitoglou et al 1988: 81, 114). There was also evidence of charcoal, burnt bone and stone in areas that did not have a hearth such as H27 and H28 (Cambitoglou et al 1988: 102, 120) and numerous locations in which *chytrai* were found (Cambitoglou et al 1988: 184-185), which indicates the use of braziers (Parisinou 2007:220 see also Lang 1996: 265 and Mazarakis Ainian 1997: 125).

The presence of a fire would have provided a source of heat for cooking and for the occupants to keep warm as well as to light the room. The hearths are not likely to have been used all of the time or in the same way throughout the year. In summer the fires in the hearths may have been relatively small or used for shorter periods of time, as they were not needed to heat the room. Nevertheless, in the summer, for those who cooked, particularly on hearths inside the house, their tasks would have been less pleasant due to the combination of high ambient temperature and the artificial heat. Ethnographic evidence from similar geographic locations in Greece would seem to suggest that during the winter months more people were likely to have spent the majority of their time within the house, carrying out activities in the vicinity of the fire (Du Boulay 1974:25). During the cold period of the year it may have been someone's role to kindle and sustain the fire. In Ambéli, during the months of October through to April, the fire was maintained by a skilled individual (usually an older woman) who remained at the fireside all day long in order to ensure that it was always lit for cooking and to maintain the temperature in the house (Du Boulay 1974:25).

One of the strongest smells in the house was most likely to have been that of smoke from the hearths. Clearly, the density of smoke would have varied at different hours of the day and also at different times of the year, according to when the hearths were used most frequently. Good ventilation through openings (like doors, windows and smoke holes or chimneys) may have removed smoke from the houses. At Zagora a triangular window formed from three flat schist stones was found in the northeast wall of room J1 and it is assumed that the use of such schist openings was widespread in the settlement (Cambitoglou et al 1971: 25). This type of window is found in modern Andriot architecture, most notably in the similarly stone-built pigeon-towers (Parisinou 2007: 215). Coulson envisaged that Unit IV-1 would have also had a window-like opening to let in light and allow smoke to escape (Coulson 1983: 32). He imagined that the opening in the gable was probably about the east end, perhaps above the main entrance and protected by the roof. There appear to be significant differences in the effectiveness of *louvres* according to where they are positioned (gable vs. ridge) (Beck et al 2007: 149). Even if, as Coulson suggested, the door and window would have admitted the warm breezes from the southeast in the summer, it is likely that Unit IV-1 was smoky when fires or braziers were lit. Studies of vernacular structures have revealed that house interiors still smell strongly of smoke and the walls and roof are often covered in soot even when a chimney, *louvre* or smoke hole is used (Beck et al 2007: 147-149; Bourdier 1997:342; McDermott 1997). In fact, in many thatched buildings the production of smoke is often encouraged not only to smoke meat and fish (Cavanagh 2006; Kaufmann 2006: xlix; Kjällstrand and Petersson 2001; McDermott

1997) but also as it is believed to act as a repellent against insects and rodents (Beck et al 2007: 149), and soot can be collected and used as a fertiliser (McDermott 1997).

Smoke from the hearths would have added a particular dimension to how the structure was experienced. In the experimental reconstructions of Iron Age houses at Sagnlandet Lejre, which were similar in form and construction to materials at the structure Unit IV-1 at Nichoria, the smoke followed the hot air from the fire to circulate around the upper interior (the greatest concentration was in the loft) before drifting through the *louvres* in the roof or filtering through the thatched roof itself. The smoke was dense forming, what the participants in the *Klima-X* experiments called, a 'thick blanket', cleaner less-smoky air was restricted to a small space from the floor up to a height of about 1.5m (Beck et al 2007: 147; 149).

Smoke within the house not only limits visibility but also movement and how people use space. In the Hebrides, for example, furniture for the occupants was created to be low slung, enabling the family to sit with their heads below the level of the smoke that accumulated in the roof space (McDermott 1997:341-342). In the case of either Nichoria or Zagora, we should assume that during the winter months, if the pit hearth or the large schist hearths were lit for long periods of the day, a dense smoke layer would have formed within the houses. Although the existence of strong smells and a blanket of smoke may have influenced how people experienced their home, the impact of domestic smoke is likely to have played a far more significant role in people's quality of life and physical wellbeing.

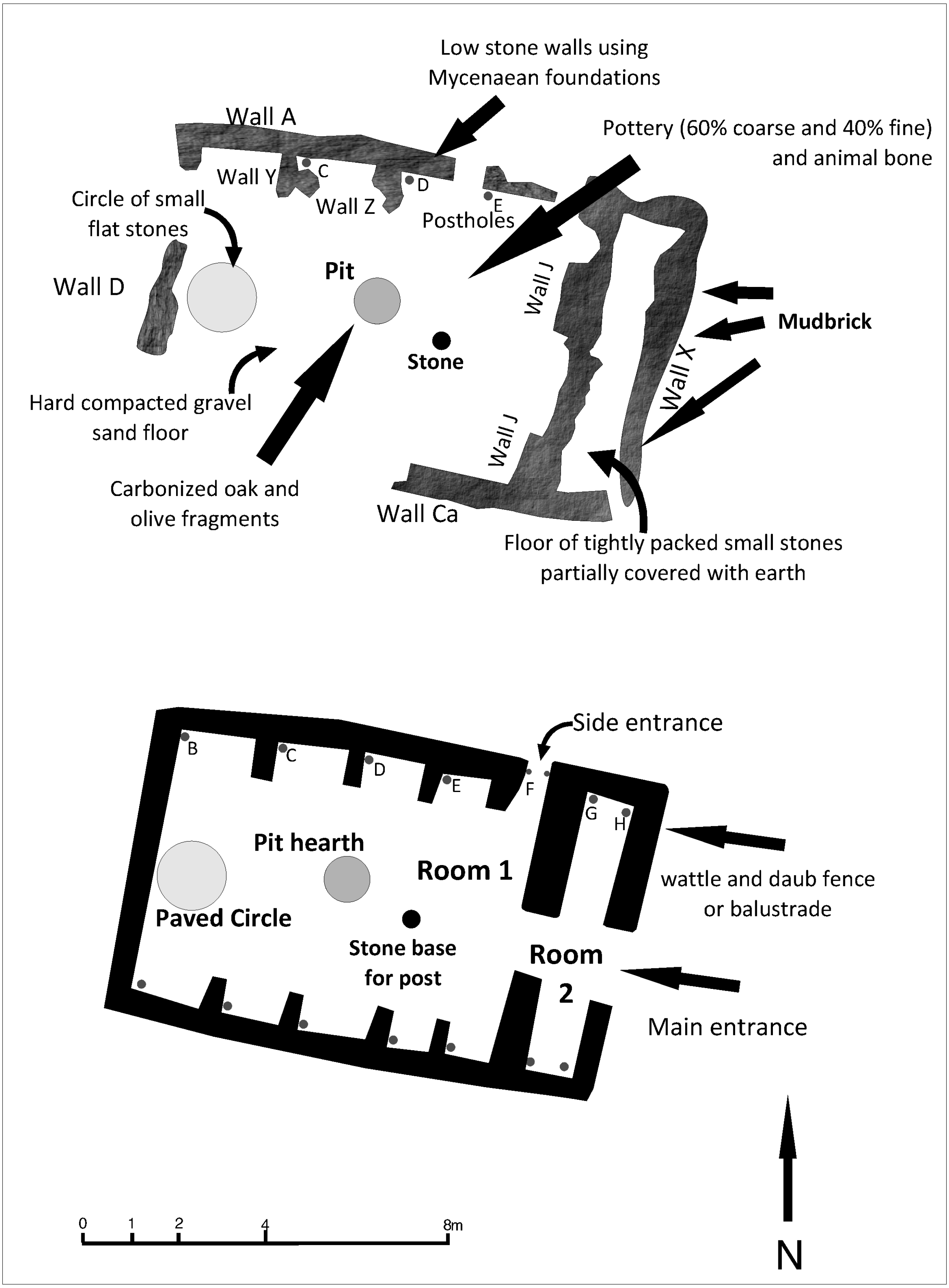

Figure 2. Plan of Unit IV-1 at Nichoria (After Coulson et al. 1983: Figure 2.11)

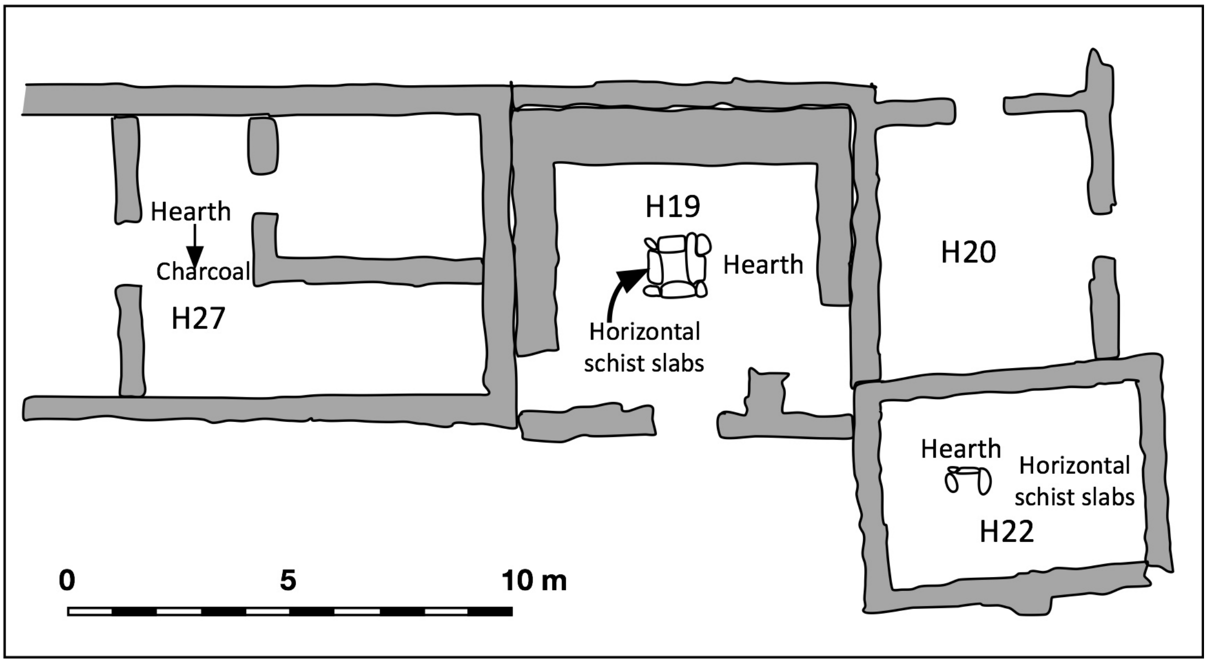

Figure 3. Plan of H19, H22 and H27 buildings at Zagora (After Cambitoglou 1988)

Air pollution in the home

The health impacts of air pollution (domestic and industrial) have been recognised for a long time. However, direct measurements of air pollution have only taken place relatively recently and systematic monitoring has only been performed in the last 50 years (Skov et al 2000: 3801). Exposure to high levels of air pollution in the distant past has been identified in frozen, dried or mummified lung tissue and by skeletal changes indicating a remarkable prevalence of *anthracosis*[1] (Brimblecombe 1987:2; Delaney and Floinn 1995: 128 cited in Beck et al 2007: 150; Ascensi et al 1996; Birch 2005:593-596). Unfortunately, we lack evidence for lung disease from Greek archaeological sites. There are examples from prehistoric and historic archaeological contexts in other parts of the Mediterranean. At Çatalhöyük, for example, a solid black residue, that has been identified as a carbon based material, was observed on the fragments of rib bones from adult individuals. It seems very probable that this carbon material was a result of the smoky carbon pollutants produced from fires (Birch 2005: 593). Closer in space and time to the Greek sites discussed here, at Grottarossa, 7km north of Rome, the mummified body of a child from the second century CE exhibits severe anthracosis, a lung disease caused by the inhalation of particulate pollutants (Ascensi et al 1996). Pleurisy, a disorder associated with pollution from the biomass used for lighting, cooking, and heating, has been detected in several bodies from Herculaneum (Capasso 2000a). There are, however, only a limited number of these examples because the identification of lung disease requires exceptionally good skeletal or soft tissue preservation.

Throughout history considerable respiratory problems[2] have been caused from domestic smoke (indoor pollution) that was produced by burning biomass (wood, dung, peat and crop residues). This is mainly reported in countries where wood and other biomasses are burned for domestic energy

[1] Carbon pigmentation of the lungs or *black lung disease is* the most common *pneumoconiosis* a group of lung diseases caused by the inhalation of dust (Flenley 1990; Stevens & Lowe 1995; Tighe 1972). Pneumoconiosis

[2] A wide range of terms have been coined to refer to the respiratory problems that are caused from domestic smoke. One of the most common is ''hut lung''.

such as daily cooking, and, periodically, for heating and lighting (Makra and Brimblecombe 2004: 642). The combustion of wood creates a high emission of numerous pollutants including Carbon Monoxide (CO), Sulfur Dioxide (SO2), Nitrogen Dioxide (NO2) and Benzene. Wood smoke also contains organic compounds and different fine particle-forming ash components and metals that constitute the Particulate Matter (PM) (Naeher et al 2007; USEPA 1993; Zelikoff et al 2002). A significant number of these wood smoke constituents are known to act as primary pollutants, irritants, and carcinogenic or cocarcinogenic compounds for the respiratory system, including PM (PM10), CO, NO2, SO2, aldehydes (such as formaldehyde), polycyclic aromatic hydrocarbons (e.g., benzopyrene), volatile organic compounds, chlorinated dioxins, and free radicals (Larson and Koenig 1994; USEPA 1993; Zelikoff et al 2002) (Table 1).

Chemical	**Grams per Kilogram of Wood**
Carbon monoxide	80 to 370
Methane	14 to 25
Volatile organic compounds (C2–C7)	7 to 27
Aldehydes	0.6 to 5.4
Substituted furans	0.15 to 1.7
Benzene	0.6 to 4.0
Alkyl benzenes	1 to 6
Toluene	0.15 to 1.0
Acetic acid	1.8 to 2.4
Formic acid	0.06 to 0.08
Nitrogen oxides (NO, NO2)	0.2 to 0.9
Sulphur dioxide	0.16 to 0.24
Methyl chloride	0.01 to 0.04
Naphthalene	0.24 to 1.6
Substituted naphthalenes	0.3 to 2.1
Oxygenated monoaromatics	1 to 7
Total particle mass	7 to 30
Particulate organic carbon	2 to 20
Oxygenated Polycyclic Aromatic Hydrocarbons	0.15 to 1

Table 1. Chemical composition of wood smoke. Source of data USEPA 1997

Experimental archaeology has been used to provide some indication of the possible levels of pollutants in ancient houses. In the *KLIMA X* experiment at Lejre a group of archaeologists spent several weeks over the course of a couple of winters living in two reconstructions of Iron Age Long houses (10 and 17). In the centre of each house was an open fireplace that was used as the primary heat source and place where food was cooked. On average 74 kg of firewood was burned daily (predominantly elm with minor quantities of ash). The main way smoke from the fireplace could escape was through the thatched roof, the doors and through *louvres* in either the ridge (House 17) or the gable (House 10). Despite the existence of ventilation the houses (particularly House 17) were often filled with smoke, which irritated the participants' eyes and their respiratory system (Beck et al 2007: 149).

Within the experiment, the level of exposure to different pollutants was recorded in House 17 over one week from 6 to 13 February 1999. The measurements revealed dangerously high levels of various toxic pollutants that were derived from the wood smoke. These included CO, NO2, Benzene, toluene and O-xylene. The personal exposure to NO was measured with four passive samplers attached to a test person as well as at three monitoring stations near the fireplace, beds and about 20m outside the house. As it was winter the fire was lit most of the time. The test person left the house for about one and half to two hours per day. Finally, 1 h average concentrations of benzene, toluene and O-xylene were measured every hour during a 24 h period as part of the exposure measurement. A weekly average exposure of NO was measured to be 61.6 mg/m3. The measurements in the house were as high as 110.8 mg/m3 and 9.9 mg/m3 outside. As a comparison it is useful to know that the concentration within the house was over twice the level as that registered on children in the heavy traffic of Copenhagen in 1994-95 (Beck et al 2007: 149; Skov et al 2000).

Benzene was the most dominant of the other three pollutants recorded. The highest concentrations of Benzene were measured during cooking at the hearth and the lowest were recorded at night when the fire had been extinguished. A 24-hour average gave a figure of 45.9 mg/m3, which constitutes a serious health risk. The limit value of Benzene in ambient air is proposed by the EU-Commission to be 5 mg/m3. The concentration of Benzene in the house was about 5 times higher than in a busy road in Copenhagen (Christensen et al. 1999 cited in Skov et al 2000), and it is more than twice the level of exposure of people living and working in Copenhagen (Raaschou-Nielsen et al. 1997). Nevertheless, the observed indoor level of Benzene of 45.8 mg/m3 is only 1/3 the exposure (150 mg/ m3) of a typical woman living in rural areas in developing countries (Zang and Smith 1996).

In contemporary contexts around the world, cooking is the most significant activity contributing to indoor air pollution. Burning biomass in traditional stoves or open-fires emits smoke containing large quantities of pollutants (Balakrishnan et al 2004; Cooper 1980; Smith 1993; Smith and Liu 1994; Zang and Smith 1996). The majority of rural households in developing countries use open fireplaces or non-airtight stoves to burn biomass fuels, which results in high levels of emissions, which, in the presence of poor ventilation, produce very high levels of indoor pollution. For example, in a typical 24-h average PM10 levels recorded in Guatemalan homes with open wood fires are 800–1000 mg/m3 (Naeher et al., 2000) and in other contexts can be up to 3,000 mg/m3. These levels may reach 30,000 mg/m3 during periods of cooking (Bruce et al 2000; Bruce et al 2004; Ezzati and Kammen 2002). In comparison, the US Environmental Protection Agency (USEPA) 99th percentile standards for 24-h average PM10 are 150 mg/m3. The mean 24-hour levels of CO in the same households are in the range of 2 to 50 ppm, and can reach 500 ppm during cooking (Boy et al., 2002). By way of contrast, the USEPA 8-h average CO standard is 9 ppm or 10 mg/m3 (USEPA 1997). In developing countries, the levels of indoor air pollution in homes using biomass fuels for cooking far exceed modern health-based standards and they also experience repeated episodes of intense emissions (Balakrishnan et al 2002; Ezzati et al 2000; Ezzati and Kaman 2001).

The methods for cooking and heating in Iron Age Greece in open hearths and with braziers were similar to those used today in many developing countries. Even without clear soft tissue or skeletal evidence from sites of ancient Greece it is highly likely that domestic structures would have been filled with high levels of pollutants that would have caused major health problems. Surprisingly, despite considerable interest in the use of wood and charcoal for fuel and in the use of hearths, cooking and the production of artificial light (Meiggs 1982: 188-190, 203-206; Olson 1991; Parisinou 2007; Tsakirgis 2007; Foxhall 2007), there has been very little discussion of the health implications for the different members of a household that would have resulted from these practices.

Gender and age related exposure to domestic pollutants

The use of biomass fuels as a source of fuel exposes all members of the family on a daily basis to levels of air pollution that exceed modern health guidelines for outdoor air quality (WHO 1997; Zang and Smith 1996). Even in a warm climate such as Andhra Pradesh, India where no space heating is required and biomass fuels are only used for cooking, and even when cooking is done outside the house in a separate kitchen or in the open air the resulting indoor levels of pollution and exposure of all family members greatly exceed health guidelines for ambient air (Balakrishnan et al 2004: 22). The level of exposure of a population or an individual who uses solid fuels is extremely variable. There are significant differences in PM levels emitted from particular types of biomass fuel. For example, the mean emission concentrations of PM_{10} from charcoal combustion can be between 87% (burning period) and 92% (smoldering period) less than emissions from unprocessed wood combustion (Ezzati et al 2000: 581).

Exposure is also a function of both the pollutant concentration in an environment and the time spent by the subject in that environment (person-time). In southern India there are important gender and age dimensions to the problem of domestic air pollution and respiratory disease. Twenty-four hour average exposure concentrations were highest for cooks and exposure to pollution was significantly different for men and women. 90% of cooks were women between the age of 16 and 60. Among non-cooks, women in the age group 61-80 years experience the highest exposures, followed by women in the age group 16-60 years (assisting cooks). Men who are between 60-80 years of age also experience higher exposures when compared to men between 16 and 60, perhaps also owing to the greater likelihood of older members of a household remaining indoors for longer periods. Even amongst children there were age and gender differences. Female children (6-15 years) who were involved in cooking reported higher exposures than other children. The exposures for children (both sexes) who were not involved in cooking were higher than adult males. Men in the 16-60 age group had the lowest exposures to pollution, which has been attributed to the length of time that they remain outdoors (Balakrishnan et al 2004: 22).

It appears that women and young children in particular are exposed to air pollution because of the length of time that they are indoors and the types of activities that they perform (Bruce et al., 2000; Bruce et al 2004). Although domestic structures may have open fires there are a range of ‘‘micro-environments’’ in and around the structure in which young children and their mothers may operate. As such a child living in a very polluted home will, on balance, encounter less polluted microenvironments when outdoors and visiting other places. However, up to half of the total exposure in women who cook with solid fuel may be derived by high-intensity episodes when they are close to a fire, especially when starting or rousing a fire. In certain situations, such as during meal preparation and cooking, levels of respirable particles may reach levels 1–2 orders of magnitude higher than accepted pollution standards in developed countries (McCracken and Smith 1998). Research in Guatemala has shown that women spend on average 5 h per day in proximity to a lit fire (Engle et al. 1997). Babies and young children (pre-toddlers) are often carried on their mothers' backs while cooking is in progress (Smith 1993) or they are placed in the vicinity of the cooking area and therefore spend many hours breathing smoke. As a result, women and children receive substantial exposure on a daily basis. The consequence of these patterns of gender and age related exposure to domestic pollutants is the prevalence of disease in children and women. The following section provides a brief introduction to some of the most endemic health problems that are caused by biomass combustion in domestic contexts.

Respiratory effects of using biomass fuels in domestic contexts

Exposure to domestic pollution is responsible for an estimated 2.6% of the total global burden of disease, or about 1.6 million premature deaths each year and over 38.5 million disability-adjusted life-years and this affects mainly children and women (Smith et al 2004). About two-thirds of this mortality is thought to be from childhood pneumonia, which itself is the largest single cause of child death globally. There is strong evidence indoor biomass smoke is the major cause and irritant of Asthma and Acute Respiratory Infections (ARI) in children younger than 5 years and Chronic Obstructive Pulmonary Disease (COPD) and lung cancer in women (Albalak et al. 1999; Dherani et al. 2008; Ezzati and Kammen 2001; 2002; Pandey 1984; Pandey et al 1985) (Table 2).

<table>
<tr><th>Pollutant</th><th colspan="2">Potential health risk and symptoms of the condition</th></tr>
<tr><td>Particulate matter (small particles <10 µm, and particularly <2.5 µm aerodynamic diameter)</td><td colspan="2">Acute: bronchial irritation, inflammation and increased reactivity causes wheezing and exacerbation of asthma (Schei et al 2004). Increased risk of respiratory infections, chronic bronchitis (Pandey 1984: 339) and cause and exacerbate Chronic Obstructive Pulmonary Disease (COPD)</td></tr>
<tr><td rowspan="6">Nitrogen Dioxide NO^2</td><td colspan="2">NO2 is known not only to irritate the respiratory system resulting in coughing, but also to lead to chronic lung diseases including Pulmonary oedema: seepage of fluid into the lungs leading to dyspnoea, blue colouration of skin, and rapid and rasping respiration with a cough, and possibly bloody phlegm. Increased susceptibility to bacterial and viral lung infections</td></tr>
<tr><td>Parts per million (ppm)</td><td>Symptoms</td></tr>
<tr><td>10-20</td><td>Irritation of eyes and respiration</td></tr>
<tr><td>20</td><td>Concentration that is immediately dangerous to life and health</td></tr>
<tr><td>100</td><td>Pulmonary oedema, perhaps deadly after 60 minutes</td></tr>
<tr><td>250</td><td>Pulmonary oedema, deadly after 5 minutes</td></tr>
<tr><td>Sulfur dioxide (SO^2)</td><td colspan="2">Short-term exposure has been linked to wheezing, chest tightness and shortness of breath. Other effects associated with longer-term exposure to sulfur dioxide, in conjunction with high levels of particulate soot, include respiratory illness, alterations in the lungs' defences and aggravation of existing cardiovascular disease.</td></tr>
<tr><td>Carbon monoxide</td><td colspan="2">Short-term effects include red eyes, sore throat, headaches and nausea. Long-term effects include the binding of CO with haemoglobin to produce carboxyhemoglobin, which reduces oxygen delivery to key organs and the developing foetus. Low birth weight (foetal carboxyhemoglobin 2–10% or higher)
Increase in perinatal deaths</td></tr>
<tr><td>Hydrocarbons</td><td colspan="2">Benzene (C_6H_4 (CH_3)) is known as a strong carcinogenic compound leading to leukaemia.</td></tr>
<tr><td>Polycyclic aromatic hydrocarbons (PAH) (e.g., benzo[a]pyrene)</td><td colspan="2">Bronchitis, lung cancer; cancer of the mouth, nasopharynx and larynx</td></tr>
</table>

Table 2. Main pollutants in biomass smoke and their associated potential health risks and symptoms of the condition. Based on data in Bruce et al 2004; Pandey 1984: 339; Schei et al 2004 and after www.kemikalieberedskab.dk cited in Beck et al 2007: 148

ARI can occur in either the upper or lower respiratory tract. Lower respiratory tract infections include pneumonia, influenza, and Respiratory Syncytial Virus (RSV). ARI causes at least 6% of the disability and death around the globe, affecting the most vulnerable populations, especially the young, the old, the ailing, and the poor. They cause the death of at least two million children younger than 5 years (Lopez et al 2006) and five million children per year under five years of age suffer from infections (Pandey 1984; Pandey et al 1985). The prevalence of Chronic Obstructive

Pulmonary Disease (COPD) is also influenced by the combustion of domestic fuel. In Latin America 50% of COPD, especially in women, occurs in people who have never smoked, and could be attributed predominantly to biomass (wood) burned in open stoves for cooking (and heating in the colder, higher altitudes) (Caballero et al 2008; Menezes et al 2005; Ramirez-Venegas *et al* 2006). The overall risk of COPD in women exposed to indoor air pollution from domestic solid fuel use, especially wood, was consistently higher (OR, 3.2; 95% CI, 2.3–4.8) than in men (OR, 1.8; 95% CI, 1.0–3.2), who were likely less exposed (Smith et al 2004). However, the persistent high levels of pollutants in living and sleeping areas at homes where biomass fuels are used has been associated with the prevalence of COPD amongst men and women (Caballero et al 2008). Maternal exposure to biomass smoke has been associated with low birth weight in neonates (Mishra 2004), with possible impairment of lung growth and development and impact on adult respiratory function and diseases.

This type of contemporary data provides some indication of the potential health problems that would have been experienced by the inhabitants of houses at Nichoria, Zagora and across the Greek world. It has implications for the way that we might think about cooking and heating in houses and importantly the experiences of those houses particularly for the individuals or groups of people who spent more time performing tasks in close proximity to the source(s) of biomass smoke. If women, children and the elderly of Iron Age Greece spent similar periods of time, performing similar tasks to contemporary populations from Spain and Turkey, through to India, Nepal and Guatemala they are likely to have experienced significant health problems that may well have lead to mortality.

These task-associated health problems also provide a fascinating glimpse into how people would have experienced not only episodes that involved the use of biomass fuel but also how their bodies were altered. Wood has powerful transformative properties. When wood is worked it has the power to produce calluses on the fingertips and hands. When it is burnt it has the power to transform the lungs. In the context of a smoke filled room we might feel irritation to the eyes, nose and throat but these irritations will be short lived. When the smoke dies down or we leave the room the irritation will reduce. Long-term exposure, in contrast, causes physiological change that affects daily activity, quality of life, perception of self and worth within the family and community and changes to social interaction. In contemporary situations many of these symptoms have lead the sufferers to develop psychological problems.

In the last decade a number of medical studies have examined the quality of life, distress and self-esteem for chronic suffers of ARI, COPD, asthma and chronic bronchitis. A common element of these studies has been that chronic illness is examined from the patients' perspective, phenomenologically, not only from the physiological symptoms that they experience but to explore the experience of adjustment and adaptation to living with the illness and to examine the subjective phenomena as presented by the patient.

Breathlessness (*Dyspnea*) is one of the major symptoms of COPD (as with all chronic respiratory conditions like chronic bronchitis). There can be significant loss of total lung function, in severe cases individuals can have <30% lung capacity. Depending on the severity and progression of a disease like COPD or chronic bronchitis breathing difficulties may limit daily activities such as walking even on level ground (Bjornsson *et al*. 1994; Nicolson and Anderson 2003). Thus consciously or unconsciously suffers of ARI, COPD and asthma will have to reduce the level of routine physical activity. In a number of studies of COPD sufferers, they revealed how they had developed strategies to cope with their symptoms. This involved pacing activities and learning to conserve energy and adapt daily tasks such as sitting down to complete tasks in the kitchen, washing and dressing (Barnett 2005). Interestingly, they developed their coping strategies by trial and error (Barnett 2005: 811). Such strategies have been described as the 'evolution of expertise' that develops over time as patients with chronic illness manage their symptoms (Paterson and Thorne 2000) and learn about how their body and their ability to perform tasks (*bodily hexis*) has changed.

Classical medical writers linked the symptoms and the frequency of occurrence of respiratory illness with the seasons of the year (Aphorisms 1.12). Contemporary research has revealed that many sufferers have discussed their newfound understanding and fear of the weather. Their symptoms and bodily practice are dictated by fluctuations in weather and extremes of hot or cold weather, humidity, contexts that are damp or steamy or that are polluted. Ingold has argued that "The *experience of weather* lies at the root of our moods and motivations; indeed it is the very temperament of our being" (2010: 122). This is particular resonant for people who suffer from respiratory illness. Their lives are determined by weather. In this sense, the weather is not so much what the sufferers perceive as what they perceive *in* (Ingold 2010: 131), it conditions their interaction with people and things as well as how they know them. Moreover, it conditions how they perceive themselves and how they deal with everyday life. Awareness of breathing difficulties, and the factors that may trigger breathing difficulties, may lead to psychological signs of distress as well as the physical. For example, sufferers of chronic bronchitis describe the potentially frightening, and often unpredictable, nature of this condition. Anxiety and panic at the idea of not being able to breathe (which includes an accumulated 'memory' of the impact of such difficulties) is related to the physical issues themselves (Nicolson and Anderson 2003: 260).

A study of asthma suffers indicates that the body and mind seem to have a mutual influence in the experience of asthma (Benner et al 1994). In essence, when sufferers felt well and were able to perform daily tasks, the body is experienced as oneself. During illness or an asthma attack, the body is experienced as an uncontrollable dense other with a will of its own (Benner et al 1994). The experiences of a range of respiratory illness appear to influence the sufferers' expectations for their future life prospects, fears related to morbidity (Nicolson and Anderson 2003: 251-252) and of self worth (Benner et al 1994). All illness, then, raises questions about the sense of self in relation to embodied existence. These questions about self are compounded, often, by the heightened sense of responsibility for being a healthy and active member of the community (Benner et al 1994; Nicolson and Anderson 2003: 261-262). People may begin to experience themselves as `different' from the person they were or expected to be before the disease took hold and these feelings involve a sense of loss, disruption and distress (Charmaz 1983; 1987; 1990; 1995: 657). Their sense of reduction of the former self to a `sick person' and loss of the real self was the strongest theme emerging from an analysis of patients with chronic bronchitis. The sense of loss represented the frustration and recognition of the inevitability of the physical and emotional deterioration that would be brought about by this disease. Symptoms of the disease, such as the production of phlegm and coughing, had a further impact on self-esteem and, sometimes, mental health (Nicholson and Anderson 2003: 263). The individual is *actively* engaged in adaptation to chronic disease, that is they do not just *witness* the deterioration of their health, they try to make sense of it and frequently try to resist it (Radley 1999). These coping strategies, whether they involve adjustment (i.e., acceptance of the `new' self) or adaptation (i.e., changing behavior) there is, according to Charmaz (1983; 1987; 1990; 1995) and Nicholson and Anderson (2003) an inevitable sense of loss of selfhood that the respondent negotiates between him/herself and his/her social environment.

Cooking and heating with biomass in Iron Age Greece would have produced domestic smoke and its associated pollutants. This review of medical studies has far reaching consequences for our understanding of cooking on hearths and braziers. For example, there are significant implications for our understanding of disease and demography that have not been considered before, in particular that women and children are likely to have suffered from severe respiratory illness and that there would have been higher mortality rates amongst certain groups of the population. These diseases would not have been restricted to women and children. Anyone who spent significant amounts of time in the proximity of wood or charcoal smoke is likely to have contracted a respiratory disease.

Particular age groups may have also been susceptible to smoke related diseases such as the elderly who may have spent more time within the house.

The studies of ARI, COPD, asthma and chronic bronchitis patients' quality of life, their sense of distress and self-esteem provides considerable insight into the ways that illness affects people and how their lives are transformed. These examples are not presented as direct correlates for the lives of the inhabitants of either Nichoria or Zagora; however, they raise important issues that we can't ignore. Illness and disease were inevitable for those who worked with or in the vicinity of open hearths, particularly if they were in enclosed spaces. Although domestic smoke is responsible for infant mortality and damage to neonates, the majority of people did not die immediately from ARI or COPD. They would have suffered with illness from the time that it developed until their death. As a consequence of developing the disease they would have had to adapt to their changing body, perhaps experiencing fatigue, shortness of breath, wheezing, and the production of sputum (Table 2). At the very least this would have required them to change their practices and to constantly learn new ways to cope with the onset of the disease(s) and the long-term debilitation of their body as well as their ability to perform tasks. If those who suffered from these diseases were less able to do the tasks that they needed to perform, they would become more dependent on the assistance of others in the household.

Breathing more easily in Olynthus

The third site, Olynthus is located in Chalcidic peninsula in northern Greece. The attention in this article is on the houses that were constructed and occupied from the fifth century BC when the town underwent significant expansion and redevelopment. The North Hill of the site was laid out as a planned settlement with an orthogonal grid plan in which houses were constructed in blocks. In the later fifth and fourth century, the settlement expanded onto the plain to the east, in an area referred to as the Villa Section. In the main area of the North hill, houses were organised and built in blocks. Each block contained ten houses, a north and south row divided by a central alley, with five houses in each row that shared party walls. Most houses were centred on an open courtyard that was nearly always located in the southern half of the house (Robinson and Graham 1938: 157-58).

The general population of Olynthus are less likely to have suffered from the kinds of respiratory problems that afflicted the populations at Nichoria and Zagora. There were two major reasons for this. The first was the use of a flue in a number of the houses and the second, and perhaps most important, was the use of charcoal-fired braziers.

Many houses at Olynthus contained what have referred to as a *kitchen-complex* that consisted of a large room (a *kitchen)* (Robinson and Graham 1938: 185-199; Cahill 2002: 89-90), or *oecus* (Mylonas 1940) and either one or two smaller rooms (*flue* and *bathroom*) that were separated from the main room by a row of pillars in almost two-thirds of the excavated kitchen-complexes (Robinson and Graham 1938: 199-204) (Figure 4). The *flue,* which was open through the second story of the house, was often paved with stone slabs and usually had a separate door to the court or pastas; the other room, if present, often contained a bathtub. A stone stairbase was found in many houses and indicates that the majority of houses had a second storey; the shared roof on a row meant that all houses in the row necessarily had the same number of stories.

The *kitchen* sometimes contained a built-stone wood-burning hearth (Robinson and Graham 1938: 186-8; Cahill 2002: 80-81; 154)[3]. Hearths were typically created from at least four limestone blocks

[3] Details of hearths have been provided for houses A vi 2, A vi 6, A vi 10, A vii 2, A vii 6, B vi 2, House of the

that were laid down to enclose a square or slightly oblong space in which the fire was built. There was a 0.20m layer of ash in most of the excavated hearths. The hearths were probably used to heat the suite of rooms rather than used for cooking[4]. The other important room in the kitchen complex was the *flue*, which was often separated from the kitchen by a row of closely spaced pillars, sometimes supported on or partly blocked by a rubble foundation. This *pillar-partition* is found in almost two-thirds of the excavated kitchen-complexes, and usually in houses in which there was evidence, such as a stairbase, that the house had two stories[5]. The pillar partition would have united the kitchen and flue. The flue was therefore an area at the end of a main room, rather than a completely separate space. This arrangement would have enabled heat from fires in the flue to heat the main room as well as allow light to enter, as the flue would have acted like a light well. The opening of the flue through the roof must have been closed to the weather whilst still allowing smoke to escape and light to enter[6].

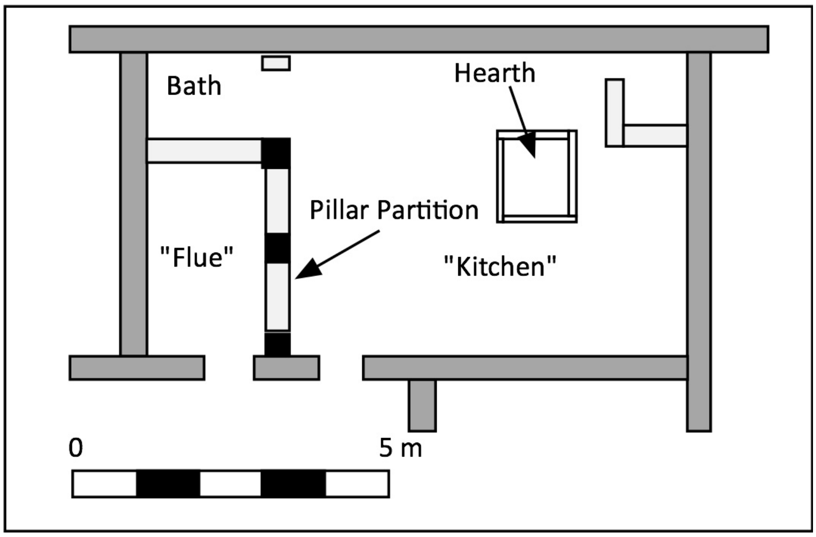

Figure 4. Plan of 'kitchen-complex' in house A vi 6 at Olynthus (After Robinson & Graham 1938)

Evidence of burning and the presence of a range of artefacts suggest that flues were used as an area for cooking and storage. Cooking and heating appears to have been with terracotta or bronze braziers[7] or other devices, and the flue was used to exhaust smoke and as a place to dispose of the ashes afterwards (Cahill 2002; Tsakirgis 2007). The majority of braziers that have been found are terracotta (for example, those in A viii 1, A v 10, A viii 8, Villa of the Bronzes, House of the Comedian, House of the Tiled Prothyron) and they are similar to those from the Athenian Agora (Robinson 1946: 5 note 9; Tsakirgis 2007).

The kitchen has been identified as an important workroom because of its size (averaging 26.3 m2) and assumed organisation of domestic activity (Robinson and Graham 1938; Mylonas 1940; Nevett 1995). Yet, the rooms contained relatively few artefacts, which do not form coherent assemblages

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Comedian, House of Many Colours, House of Twin Erotes in Robinson and Graham (1938: 186-188) and Robinson (1946: 187, 198, 371, 382, 383, 393, 394)

[4] This interpretation of the hearths' function is based on the fact that, apart from A vi 6, they contained no objects (Robinson 1946: 371).

[5] All houses had *kitchen-complexes* but they did not all have *pillar-partitions*.

[6] It is possible that the flue was covered with tiles as evidence was found in the flue of the House of Many Colors and a few other houses. There may not have been a standard way to cover the flue.

[7] Bronze braziers were found in A xi 10 (Robinson and Graham 1938: 128 186; Robinson 1946: 235, 242) and The Villa of the Bronzes (Robinson 1946: 235)

(Cahill 2002: 156). This may be because activities appear to have taken place in different parts of the house in antiquity as a strategy to make efficient use of natural light and heat at different times in the day or in the different seasons of the year (Nevett 2010: 106-107). At Olynthus, it would have made more sense to concentrate activities in the kitchen complex during the winter months. Members of the household would congregate in the complex because it was easier to keep these rooms warm without suffering the effects of too much smoke because of the presence of the flue, in contrast, during the hotter, summer months activities may have taken place in a greater number of rooms that were more comfortable for the particular task because of their natural light, size and temperature. The use of portable braziers seems to suggest that some households may well have cooked in spaces other than the flue (Cahill 2002: 160-161). It would have been possible to cook in the well-ventilated courtyard in good weather or under cover of a doorway or portico in inclement weather. This appears to have been the common pattern in houses at other Greek sites, which seem to lack specialized cooking areas (Tsakirgis 2007). The low number of objects in the kitchen complex and the distribution of objects in other areas of the houses probably reflect how the houses were organized in the late summer, when the city was destroyed.

The braziers would have burnt charcoal rather than wood. Charcoal yields much more heat per kilogram than even dry wood and is therefore a more efficient source of heat which means that it is much better suited for domestic cooking and heating as well as for blacksmithing and ironworking (Olson 1991: 412 and note 5). Importantly for the inhabitants of Olynthus, the mean emission concentrations of PM10 from charcoal combustion can be between 87% (burning period) and 92% (smouldering period) less than emissions from unprocessed wood combustion (Ezzati et al 2000: 581). Wood smoke has a more direct effect on pulmonary function than charcoal smoke. The use of charcoal rather than wood fuel appears to reduce the incidence of major respiratory disease such as COPD (Fullerton et al 2011) and wood smoke contains more airborne endotoxin than charcoal (Semple et al 2010). At first glance it might appear that very few people would have suffered from respiratory disease, unfortunately, the reality would have been somewhat different.

Despite the use of braziers we know that there would have been smoke in a house. On more than one occasion ancient literature refers to the levels of smoke in a kitchen and the effect that this has on people's eyes and clothes. Even if the smoke produced by burning charcoal contained fewer pollutants than the smoke produced by wood smoke on a burning hearth the pollutant levels were likely to have been higher than current recommended levels. Research in Africa on the effect of burning biomass on the health of the household (Ezzati et al 2000) suggests that although charcoal stoves reduced the emission level to 300 íg/m3, this was double the US EPA standard for PM10, which requires a twenty-four-hour average of no more than 150 íg/m3. Stoves need to be well sealed and vented to reduce pollutant levels to international environmental standards. We know that this was not the case at Olynthus. Consequently, whoever was responsible for the majority of household tasks, including cooking, would have been at risk of developing COPD. In Spain there is a strong statistically significant association between wood and charcoal smoke exposure and COPD in women which is connected to their dominant position in domestic tasks (Orozco-Levi et al 2006). There is also an association between length of exposure and COPD suggesting a dose–response pattern and a seasonal relationship between the intensity of exposure to smoke and the development of COPD (Orozco-Levi et al 2006).

The incidence of respiratory diseases in Classical Olynthus was likely to have been higher in people who were involved in food production on a non-domestic scale and other forms of household industry. House A viii 8 has been identified as a baking establishment. Room f of this house contained a large stone mortar and a large stone trough with two basins along with fragments of coarse wares that may have been from basins, lekanai, and storage bins for flour and other food. In the other corner of the house was a complex of three rooms (h, i, and j). The largest room, j, was cobbled; its floor was covered with ash, particularly in the southeast corner, and contained large amounts of kitchen pottery. This room was probably used for baking and cooking. The southern half of House ESH 4 may have been used, in part, for non-household cooking or some related commercial endeavour. There were two kitchen-complexes in ESH 4 that were equipped with an unusual amount of food-processing equipment including one lower and four upper grindstones and a stone mortar. Another house that may have had higher levels of smoke was A iv 7. Although there are no distinct traces of a furnace a lot of ash was found on the floor of room h, and this may mark the remains of a furnace that was used for the minting of counterfeit coins (Cahill 2002:259-261). The bakery, cooking establishment and mint would have had certain rooms that were particularly smoky with unhealthy levels of airborne pollutants. The quality of life of a baker or cook may not have been particularly high in Olynthus even if they lived in large well-equipped houses.

Perhaps even more significant is the health of the charcoal makers like Syros who plays a central role in Menander's *Epitrepontes*. Although the producers of charcoal are likely to have worked and perhaps even lived outside the city, their everyday practices and health were intimately tied to the households of Olynthus. Contemporary charcoal workers in Crete and Brazil are often exposed to wood smoke for extended periods of time in the day and to a high number of days in every week. Workers in several studies were found to have significantly more eye and throat irritation, cough, sputum production, wheezing, dyspnea, and hemoptysis sinusitis, tuberculosis, lung diseases than a control group (Kato et al 2005; Tzanakis et al 2001). The prevalence of respiratory symptoms was significantly elevated during the main exposure period (Tzanakis et al 2001). Complaints of daily headache and irritation associated with work were reported from all charcoal workers in one study (Tzanakis et al 2001). Increased respiratory symptoms and worsening of lung function found in these studies was associated with smoke exposure because of the pyrolyzing of wood to produce charcoal. Whilst the occupants of Olynthus may have breathed more easily because of the use of charcoal, they did so at the expense of the charcoal makers.

Conclusions

The rich data for the transformation of domestic environment from these three sites partly supports the argument that economic development and improved standards of living occurred across the Greek world over the course of the first millennium BC. It is clear, though, that we will always encounter difficulties when we are attempting to evaluate quality of life in the ancient world. More importantly, though, this research has highlighted the fact that there are many different determinants of wellbeing, and that this is an issue that is not adequately dealt with just by looking at house size. The evidence for cooking and heating in the home, combined with the data from medical and public health research as well as experimental archaeology raise new questions about quality of life in the ancient world that are poorly served by meta-narratives based solely on calculations of economic development. It is only by appreciating a wide range of indices, more in line with the HDI or GNH, that can arrive at a better understanding of quality of life. This has relevance not only for those who study the ancient Greek world but for all systematic studies of past wellbeing.

A number of scientific studies of human remains have revealed incidence of chronic lung disease including pleurisy and anthracosis in individuals of different age groups across the Mediterranean at this time (Ascensi et al 1996; Birch 2005: 593; Capasso 2000a and b). Although we lack either the skeletal or soft tissue evidence for incidence of these problems in Greece we have strong archaeological evidence that people used open hearths and braziers for cooking and heating in the houses at Nichoria, Zagora and Olynthus. The domestic smoke created by burning wood or charcoal in these hearths and braziers would have been a dominant factor in the way that people experienced the home. Critically, breathing in smoke created from biomass fuel produced on hearths and braziers would have had profound impact on people's state of physical wellbeing and their quality of life. This is particularly relevant because, if we believe the classical literature and a wide body of historical research, a significant component of ancient Greek society, particularly women, children and the elderly, were likely to have spent extensive periods of time in the home. The evidence from ancient Rome (Ascensi et al 1996) and contemporary medical studies (Balakrishnan et al 2004: 22; Smith 1993) indicate that even relatively young children can contract severe respiratory problems. All of these observations converge in pointing to relatively high levels of disease across the Greek world up to and including during the Classical period. Economic development did not preclude the development of illness. This may seem like an obvious point but it is often overlooked by those interested in economic history. Appreciating the impact of biomass smoke has considerable consequences for our understanding of disease and demography, in particular that women and children are likely to have suffered from severe respiratory illness (for example Acute Respiratory Infections, Chronic Obstructive Pulmonary Disease, Asthma and chronic Bronchitis) whereas those who spent more time away from the home are likely not to have suffered to a similar extent.

In addition, this article has highlighted some interesting implications for the way we have traditionally thought about cooking and heating in houses as well as the experiences of domestic space, particularly for the individuals or groups of people who spent more time performing tasks in close proximity to the source(s) of smoke. Sufferers of chronic illness would have had to change their day-to-day routines and learn new ways to perform tasks in order manage their symptoms. Furthermore, the symptoms and sufferers are likely to have been seasonally affected. The development of chronic disease would have had a profound impact on the way that individuals felt about themselves, their relationship to others in the house and wider community, as well as their quality of life.

There are also interesting implications for how we understand modifications and transformations to house styles in Greece and the wider ancient Mediterranean that extend beyond explanations of economic development or social organisation. Smoke may have been, amongst other things, a factor in the changes in house plan that we see at Zagora and in other houses of sixth century Greece. For example, between 750 and 725 BC, unit H24/25/32 at Zagora, which was a simple *megaron* house in which cooking, storage, eating, and drinking all went on in the one main room, was transformed into a three-roomed structure. The finds seem to indicate that these three new rooms were used solely for storage, however, the absence of evidence of burning and cooking may have been because cooking was performed on portable braziers that have left no residue on the floors. By 700 BC, the south wall of the old porch (H33) was extended eight meters, and two new rooms, H40 and H41, were built to the west. H40 was probably an anteroom to H41, the unit that contained a large stone hearth and sherds from fine cups.

The development and division of single roomed structures into multi-roomed homes with functionally specific rooms at Zagora, and at most other Aegean communities over the next hundred years, has been associated with the expression of privacy, ideas of gendered space (Morris 1999; Nevett 2007:211) and improved standards of living (Morris 2004; 2005: 91-126). To these explanations I would add that the development of multi-roomed houses and the increasing evidence for the use of braziers with charcoal alongside the use of some fixed hearths would have transformed the everyday embodied experiences of Greek communities. I am not suggesting that the inhabitants of Zagora and similar communities had established a causal link between smoke and their state of health but the changes that we see in the domestic record may represent a decision to separate daily life from smoky environments. Dining around an open hearth was restricted to a space in the house, whereas other activities could take place away from this major source of smoke.

If people remodelled their house they must have had good reasons to do so (Morris 1999: 310). Perhaps creating a less smoky house was a perfect reason. The major changes in house design and use that are seen from around 700 BC would have been highly significant for day-to-day existence and for the long-term quality of life of the household, perhaps more significant for the lives of all of the community than the changes in graves and sanctuaries that are also seen at this period.

If we follow traditional lines of argument by the Classical period people had better standards of living because of economic development. At Olynthus although certain technical developments had the potential to reduce the incidence of respiratory problems it would not have been removed from the population. Women, children and elderly men would still have been the most likely cohorts to have suffered from respiratory illness because of their proximity to smoke and the length of time in contact particularly during the colder months of the year. Furthermore, although some houses had flues, several houses, which are some of the largest and most elaborately decorated, had open hearths, which would have caused a higher incidence of medical problems in the winter months.

It is undeniable that houses at Olynthus appear to have been more luxurious than some of the structures at Nichoria and Zagora. House size and form support the argument that there was a relationship between increasing house size and improved standards of living between 800 and 300 BC. Crucially though, any analysis of quality of life, living standards and physical wellbeing needs to be based on much more than the trend in median house sizes and changing fabric of houses. Some of the largest and most elaborate houses at Olynthus had substantial limestone hearths in their kitchen. The inhabitants of these houses may have thought that they were living in luxury but their physical wellbeing, particularly in winter months when they spent more time warming themselves at their open fire, would not have been much different from the inhabitants of Iron Age Nichoria because they were likely to have suffered from a variety of smoke-related health problems. Clearly, it is not sufficient to assume that we can read changes in house form and content as markers of economic development and improved standards of living in ancient Greece. Comprehending living standards requires us to think much more about the practicalities and experiences of daily life.

Bibliography

Albalak, R., A. R. Frisancho & G. J. Keeler, 1999. Domestic biomass fuel combustion and chronic bronchitis in two rural Bolivian villages. *Thorax*, 54, 1004-8.

Arnott, R. 2005. Disease and the prehistory of the Aegean, in *Health in Antiquity*, ed. H. King. London: Routledge, 12-31.

Ascensi A, Bianco P, Nicoletti R, et al. 1996. The Roman mummy of Grottarossa, in *Human mummies* eds. K. Spindler, H. Wilfing, E. Rastbichler-Zisserning, D. zurNedden & H. Nothdurfter Wien: Spinger, 205–18.

Balakrishnan, K., S. Sambandam, P. Ramaswamy, S. Mehta & K. Smith, 2004. Exposure assessment for respirable particulates associated with household fuel use in rural districts of Andhra Pradesh, India. *Journal of Exposure Science and Environmental Epidemiology*, 14, 14-25.

Barnett, M., 2005. Chronic obstructive pulmonary disease: a phenomenological study of patients' experiences. *Journal of Clinical Nursing*, 14, 805-12.

Beck, A. S., L. M. Christensen, J. E. Rune, B. Larsen, D. Larsen, N. A. Møller, T. Rasmussen, L. Sørensen & L. Thofte, 2007. Reconstruction – and then what? Climatic experiments in reconstructed Iron Age houses during Winter, in *Iron Age houses in flames. Testing house reconstructions at Lejre*, ed. M. Rasmussen Lejre: Lejre Experimental Center, 134-73.

Benner, P., S. Janson-Bjerklie, S. Ferketich & G. Becker, 1994. Moral dimensions of living with a chronic illness: autonomy, responsibility, and the limits of control, in *Interpretive Phenomenology: Embodiment, Caring and Ethics in Health and Illness*, ed. P. Benner London: SAGE, 225-54.

Birch, W., 2005. A possible case of shortness of breath at Çatalhöyük – black lungs, in *Inhabiting Çatalhöyük: reports from the 1995-99 seasons*, ed. I. Hodder Cambridge: McDonald Institute for Archaeological Research/British Institute of Archaeology at Ankara, 593-6.

Bjornsson, E., P. Plaschke, E. Norrman, C. Janson, B. Lundback, A. Rosenhall, N. Lindholm, L. Rosenhall, E. Berglund & G. Boman, 1994. Symptoms related to asthma and chronic bronchitis in three areas of Sweden. *European Respiratory Journal*, 7, 2146-53.

Bourdier, J.-P., 1997. Smoke holes, in *Encyclopaedia of vernacular architecture of the world*, ed. P. Oliver Cambridge: Cambridge University Press, 342.

Brimblecombe, P., 1987. *The Big Smoke. A History of Air Pollution in London Since Medieval Times*, London: Metheun.

Bruce, N., J. McCracken, R. Albalak, M. Schei, K. Smith, V. Lopez & C. West, 2004. Impact of improved stoves, house construction and child location on levels of indoor air pollution exposure in young Guatemalan children. *Journal of Exposure Science and Environmental Epidemiology*, 14, 26-33.

Bruce, N., R. Perez-Padilla & R. Albalak, 2000. Indoor air pollution in developing countries: a major environmental and public health challenge. *Bulletin of the World Health Organization*, 78, 1078-92.

Caballero, A., C. A. Torres-Duque, C. Jaramillo, F. Bolívar, F. Sanabria, P. Osorio, C. Orduz, D. P. Guevara & D. Maldonado, 2008. Prevalence of COPD in Five Colombian Cities Situated at Low, Medium, and High Altitude (PREPOCOL Study). *Chest*, 133, 343-9.

Cahill, N., 2002. *Household and city organization at Olynthus*, New Haven: Yale University Press.

Cambitoglou, A., J. J. Coulton, J. Birmingham & J. R. Green, 1971. *Zagora 1; excavation season 1967; study season 1968-9*, Sydney: Sydney University Press for the Australian Academy of the Humanities.

Cambitoglou, A., A. Birchall, J. J. Coulton & J. R. Green, 1988. *Zagora 2: excavation of a geometric town on the island of Andros; excavation season 1969, study season 1969-1970*, Athens: Athens Archaeological Society.

Capasso L. 2000a. Herculaneum victims of the volcanic eruptions of Vesuvius in 79 AD. *Lancet,* 356, 1344–46.

Capasso L. 2000b. Indoor pollution and respiratory diseases in Ancient Rome. *Lancet,* 356, 1774.

Cavanagh, W., 2006. Food preservation in Greece during the Late and Final Neolithic periods, in *Cooking up the Past: Food and Culinary Practices in the Neolithic and Early Bronze Age Aegean*, eds. C. Mee & J. Renard Oxford: Oxbow, 109-22.

Charmaz, K., 1983. Loss of self: a fundamental form of suffering in the chronically ill. *Sociology of Health & Illness*, 5, 168-95.

Charmaz, K., 1987. Struggling for a self: identity levels of the chronically ill. *Research in the Sociology of Health Care*, 6, 283-321.

Charmaz, K., 1990. Discovering chronic illness: Using grounded theory. *Social Science & Medicine*, 30, 1161-72.

Charmaz, K., 1995. The body, identity, and self: Adapting to impairment. *Sociological Quarterly*, 657-80.

Christensen, C., H. Skov & F. Palmgren, 1999. C5-C8 non-methane hydrocarbon measurements in Copenhagen: concentrations, sources and emission estimates. *The Science of the Total Environment*, 236, 163-71.

Cooper, J. A., 1980. Environmental impact of residential wood combustion emissions and its implications. *Journal of Air Pollution Control Association*, 30, 855-86.

Coulson, W. D. E., 1983. The Architecture, in *Excavations at Nichoria in Southwest Greece, Volume 3: Dark Age and Byzantine Occupation*, eds. W. A. McDonald, W. D. E. Coulson & J. Rosser Minneapolis: University of Minnesota Press, 9-60.

Delaney, M. & R. O' Floinn, 1995. A body body from Meenybradden Bog, County Donegal, Ireland, in *Bog Bodies*, eds. R. C. Turner & R. G. Scaife London: British Museum Press, 123-32.

Dherani, M., D. Pope, M. Mascarenhas, K. R. Smith, M. Weber & N. Bruce, 2008. Indoor air pollution from unprocessed solid fuel use and pneumonia risk in children aged under five years: a systematic review and meta-analysis. *Bulletin of the World Health Organization*, 86, 390-8.

Du Boulay, J., 1974. *Portrait of a Greek Mountain Village.* Oxford: Clarendon press.

Ezzati, M. & D. M. Kammen, 2001. Indoor air pollution from biomass combustion and acute respiratory infections in Kenya: an exposure-response study. *The Lancet*, 358, 619-24.

Ezzati, M. & D. M. Kammen, 2002. The health impacts of exposure to indoor air pollution from solid fuels in developing countries: knowledge, gaps, and data needs. *Environmental Health Perspectives*, 110, 1057.

Ezzati, M., B. M. Mbinda & D. M. Kammen, 2000. Comparison of emissions and residential exposure from traditional and improved cookstoves in Kenya. *Environmental Science & Technology*, 34, 578-83.

Foxhall, L., 2007. House clearance: unpacking the 'kitchen' in Classical Greece, in *Building Communities: House settlement and society in the Aegean and beyond: proceedings of a conference held at Cardiff University 17-21 April 2001*, eds. R. Westgate, N. Fisher & J. Whitley London: British School at Athens, 233-42.

Fullerton, D. G., Suseno, A., Semple, S., Kalambo, F., Malamba, R., White, S., Jack, P. M. Calverley, & Gordon, S. B. 2011. Wood smoke exposure, poverty and impaired lung function in Malawian adults. *The International Journal of Tuberculosis and Lung Disease*, 15, 391-398.

Hoepfner, W. & E. L. Schwandner, 1986. *Haus und Stadt im klassichen Griechenland*, München: Deutscher Kunstverlag.

Ingold, T., 2010. Footprints through the weather-world: walking, breathing, knowing. *Journal of the Royal Anthropological Institute*, 16, s121-39.

Jameson, M. H., 1990. Domestic space in the Greek city-state, in *Domestic architecture and the use of space: an interdisciplinary cross-cultural study*, ed. S. Kent Cambridge: Cambridge University Press, 92-113.

Jameson, M. H., 1990. Private space in the Greek city-state, in *The Greek City from Homer to Alexander*, eds. O. Murray & S. Price Oxford: Clarendon Press, 171-95.

Kato, M., Demarini, D. M., Carvalho, A. B., Rego, M. A. V., Andrade, A. V., Bonfim, A. S. V., & Loomis, D. 2005. World at work: charcoal producing industries in northeastern Brazil. *Occupational and Environmental Medicine*, 62, 128-132.

Kaufmann, C. K., 2006. *Cooking in ancient Civilisations*, Westport, CT: Greenwood Press.

King, H. Ed. 2004. *Health in Antiquity*. London: Routledge.

Kjällstrand, J. & G. Petersson, 2001. Phenolic antioxidants in alder smoke during industrial meat curing. *Food Chemistry*, 74, 85-9.

Kron, G. 2005. Anthropometry, Physical Anthropology, and the Reconstruction of Ancient Health, Nutrition, and Living Standards. *Historia,* 54, 68-83.

Lang, F., 1996. *Archaische Siedlungen in Griechenland: Struktur und Entwicklung*, Berlin: Akademie Verlag.

Larson, T. V. & J. Q. Koenig, 1994. Wood smoke: emissions and noncancer respiratory effects. *Annual Review of Public Health*, 15, 133-56.

Lopez, A. D., C. D. Mathers, M. Ezzati, D. T. Jamison & C. J. L. Murray, 2006. Global and regional burden of disease and risk factors, 2001: systematic analysis of population health data. *The Lancet*, 367, 1747-57.

Makra, L. & P. Brimblecombe, 2004. Selections from the history of environmental pollution, with special attention to air pollution. Part 1. *International Journal of Environment and Pollution*, 22, 641-56.

Mazarakis-Ainian, A., 1997. *From Rulers' Dwellings to Temples: Architecture, Religion and Society in Early Iron Age Greece (1100-700 BC)*. Lund: Åström.

McCracken, J. P. & K. R. Smith, 1998. Emissions and efficiency of improved woodburning cookstoves in Highland Gatemala. *Environment International*, 24, 739-47.

McDermott, D., 1997. Smoke holes, in *Encyclopaedia of vernacular architecture of the world*, ed. P. Oliver Cambridge: Cambridge University Press, 341-2.

McDonald, W. A., W. D. E. Coulson & J. Rosser, 1983. *Excavations at Nichoria in Southwest Greece III. Dark Age and Byzantine Occupation*, Minneapolis: University of Minnesota Press.

Meiggs, R., 1982. *Trees and Timber in the Ancient Mediterranean World*, Oxford: Clarendon Press.

Menezes, A. M. B., R. Perez-Padilla, J. R. B. Jardim, A. Muiño, M. V. Lopez, G. Valdivia, M. M. de Oca, C. Talamo, P. C. Hallal & C. G. Victora, 2005. Chronic obstructive pulmonary disease in five Latin American cities (the PLATINO study): a prevalence study. *The Lancet*, 366, 1875-81.

Mishra, V., X. Dai, K. R. Smith & L. Mika, 2004. Maternal exposure to biomass smoke and reduced birth weight in Zimbabwe. *Annals of Epidemiology*, 14, 740-7.

Morris, I., 1999. Archaeology and gender ideologies in early archaic Greece. *Transactions of the American Philological Association,* 129, 305-17

Morris, I., 2000. *Archaeology as cultural history: words and things in Iron Age Greece*. Blackwell: Oxford.

Morris, I., 2004. Economic Growth in Ancient Greece. *Journal of Institutional and Theoretical Economics,* 160, 709-742.

Morris, I., 2005. Archaeology, standards of living, and Greek economic history, in *The Ancient Economy: Evidence and models*, eds. J. G. Manning & I. Morris Stanford: Stanford University Press, 91-126.

Naeher, L. P., M. Brauer, M. Lipsett, J. T. Zelikoff, C. D. Simpson, J. Q. Koenig & K. R. Smith, 2007. Woodsmoke health effects: a review. *Inhalation Toxicology*, 19, 67-106.

Naeher, L. P., B. P. Leaderer & K. R. Smith, 2000. Particulate matter and carbon monoxide in highland Guatemala: indoor and outdoor levels from traditional and improved wood stoves and gas stoves. *Indoor Air*, 10, 200-5.

Nevett, L. C., 1999. *House and society in the ancient Greek world*, Cambridge: Cambridge University Press.

Nevett, L. C., 2007. Housing and Households, in *Classical Archaeology*, eds. S. E. Alcock & R. Osborne Oxford: Blackwell Publishing, 205-23.

Nevett, L. C., 2010. *Domestic Space in Classical Antiquity*, Cambridge: Cambridge University Press.

Nicolson, P. & P. Anderson, 2003. Quality of life, distress and self-esteem: A focus group study of people with chronic bronchitis. *British Journal of Health Psychology*, 8, 251-70.

Olson, S., 1991. Firewood and charcoal in Classical Athens. *Hesperia*, 60, 411-20.

Orozco-Levi, M., J. Garcia-Aymerich, J. Villar, A. Ramírez-Sarmiento, J. M. Antó & J. Gea, 2006. Wood smoke exposure and risk of chronic obstructive pulmonary disease. *European Respiratory Journal*, 27, 542-6.

Pandey, M. R., 1984. Domestic smoke pollution and chronic bronchitis in a rural community of the Hill Region of Nepal. *Thorax*, 39, 337-9.

Pandey, M. R., H. N. Regmi, R. P. Neupane, A. Gautam & D. P. Bhandari, 1985. Domestic smoke pollution and respiratory function in rural Nepal. *Tokai Journal of Experimental and Clinical Medicine*, 10, 471-81.

Parisinou, E., 2007. Lighting dark rooms: some thoughts about the use of space in early Greek domestic architecture, in *Building Communities: House settlement and society in the Aegean and beyond: proceedings of a conference held at Cardiff University 17-21 April 2001*, eds. R. Westgate, N. Fisher & J. Whitley London: The British School at Athens, 213-23.

Paterson, B. & S. Thorne, 2000. Developmental evolution of expertise in diabetes self-management. *Clinical Nursing Research*, 9, 402-19.

Raaschou-Nielsen, O., H. Skov, C. Lohse, B. L. Thomsen & J. H. Olsen, 1997. Front-door concentrations and personal exposures of Danish children to nitrogen dioxide. *Environmental Health Perspectives*, 105, 964-70.

Radley, A., 1999. Social realms and the qualities of illness experience, in *Qualitative health psychology: theories & methods*, eds. M. Murray & K. Chamberlain London: SAGE, 16-30.

Ramirez-Venegas, A., R. H. Sansores & Perez-Padilla. R, 2006. Survival of patients with chronic obstructive pulmonary disease due to biomass smoke and tobacco. *American Journal of Respiratory and Critical Care Medicine*, 173, 393-7.

Roberts C, Lucy D, & K. Manchester, 1994. Inflammatory lesions of ribs: an analysis of the Terry Collection. *American Journal of Physical Anthropology,* 95, 169–82.

Roberts, C., Bourbou, C., Lagia, A., Triantaphyllou, S. & A. Tsaliki, 2005. Health and disease in Greece: past, present and future. in *Health in Antiquity*, ed. H. King. London: Routledge, 32-58

Robinson, D. M., 1946. *Excavations at Olynthus Part 12: Domestic and public architecture*. Baltimore:

The Johns Hopkins Press.

Robinson, D. M. & J. W. Graham, 1938. *Excavations at Olynthus Part 8 The Hellenic house: a study of the houses found at Olynthus with a detailed account of those excavated in 1931 and 1934*. Baltimore: The Johns Hopkins Press.

Schei, M., J. Hessen, K. Smith, N. Bruce, J. McCracken & V. Lopez, 2004. Childhood asthma and indoor woodsmoke from cooking in Guatemala. *Journal of Exposure Science and Environmental Epidemiology*, 14, 110-7.

Scheidel, W. 2010. Real Wages in Early Economies: Evidence for Living Standards from 1800 BCE to 1300 CE. *Journal of the Economic and Social History of the Orient* 53: 425-462.

Scheidel, W. 2010. *Human development and quality of life in the long run: the case of Greece*. Version 1.0. September 2010. Princeton/Stanford Working Papers in Classics.

Schepartz, L. A., Fox, S. C., & C. Bourbou. Eds. 2009. *New Directions in the Skeletal Biology of Ancient Greece.* Vol. 43. Princeton, N.J.: American School of Classical Studies at Athens.

Semple S, Devakumar D, Fullerton D.G, Thorne P.S, Metwali N, Costello A, Gordon S.B, Manandhar D.S & A. J.G., 2010. Airborne endotoxin concentrations in homes burning biomass fuel. Environmental Health Perspectives. *Environmental Health Perspectives*, 118, 988-91.

Skov, H., C. Stenholt Christensen & J. Fenger, 2000. Exposure to indoor air pollution in a reconstructed house from the Danish Iron Age. *Atmospheric Environment*, 34, 3801-4.

Smith, K. R., 1993. Fuel combustion, air pollution exposure, and health: the situation in developing countries. *Annual Review of Energy and the Environment*, 18, 529-66.

Smith, K. R. & Y. Liu, 1994. Indoor air pollution in developing countries, in *Epidemiology of Lung Cancer. Lung Biology in Health and Disease*, ed. J. Samet New York: Marcel Dekker.

Smith, K. R. R., S. Mehta & M. Maeusezahl-Feuz, 2004. Indoor air pollution from household use of solid fuels: Comparative quantification of health risks, in *Global and regional burden of disease attributable to selected major risk factors*., eds. M. Ezzati, A. Lopez, A. Rodgers & C. Murray Geneva: World Health Organization, 1436-93.

Steckel, R. H. 2009. Heights and Human Welfare: Recent Developments and New Directions. *Explorations in Economic History,* 46, 1-23.

Steckel, R. H. 2013. Biological Measures of Economic History. *Annual Review of Economics*, 5, 401-423.

Tsakirgis, B., 2007. Fire and Smoke: Hearths Braziers and Chimneys in the Greek House, in *Building Communities : House settlement and society in the Aegean and beyond: proceedings of a conference held at Cardiff University 17-21 April 2001*, eds. R. Westgate, N. Fisher & J. Whitley London: British School at Athens, 225-31.

Tzanakis, N., K. Kallergis & D. E. Bouros, 2001. Shortterm effects of wood smoke exposure on the respiratory system among charcoal production workers. *Chest*, 119, 1260-5.

United States Environmental Protection Agency (USEPA). 1997. *Revisions to the National Ambient Air Quality Standards for Particulate Matter*. Federal Register July 18, 1997, 62.

Westgate, R., N. Fisher & J. Whitley (eds.), 2007. *Building Communities : House settlement and society in the Aegean and beyond: proceedings of a conference held at Cardiff University 17-21 April 2001*, London: British School at Athens.

World Health Organisation, 1997. *Health and Environment in Sustainable Development*, Geneva: World Health Organisation.

Zang, J. & K. H. Z. Smith, 1996. Hydrocarbon emissions and health risks from cookstoves in developing countries. *Journal of Exposure Analysis Environmental Epidemiology*, 6, 147-61.

Zelikoff, J. T., L. C. Chen, M. D. Cohen & R. B. Schlesinger, 2002. The toxicology of inhaled woodsmoke. *Journal of Toxicology and Environmental Health Part B: Critical Reviews*, 5, 269-82.